RECIPROCAL RELATIONSHIPS IN THE BRAIN-STEM AMONG AFFERENT IMPULSES FROM EACH JAW MUSCLE ON THE CAT*

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In our previous papers1,2) it has been reported that spontaneous discharges of the trigeminal motor nucleus and mesencephalic trigeminal nucleus are accelerated by stretching an ipsilateral jaw muscle, and characteristic projections of the spindle afferent impulses from each masticatory muscle in these nuclei were observed.

In the present experiment the functional interactions of the impulses from each jaw muscle in these nuclei were studied.

METHOD

Nine adult cats were used. The experimental procedures employed were almost the same as those described in the previous reports. But in this experiment, after ablation of the occipital bone the cerebellum was sucked out by means of a vacuum pump under ether anesthesia to expose the midbrain and bulb. Decerebration was not carried out. The surface of the exposed brain parts was covered with liquid paraffin kept at 37°C. In order to stretch each masticatory muscle separately, a small hook connected to the load (50-200 g) by a cotton thread was attached at the free end of each jaw muscle.

In some cases a microelectrode (1 µ, at the tip) filled with 3 M KCL, followed by a D-C amplifier and a cathode ray oscilloscope was used to get a precise record of the unit potential. The site of the recording electrode was verified histologically.

RESULTS

The sites of the recording electrode tip in the trigeminal motor nucleus and mesencephalic trigeminal nucleus are shown in Fig. 1.

1. Stretching the antagonistic muscles; Background electrical activity recorded from above cited point of the trigeminal motor nucleus was accelerated by

Received for publication April 23, 1960.
* Presented in part at the 22nd meeting of the Kinki Division of the Physiological Society of Japan, Kobe, February 6, 1960.
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jaw depression. However, this acceleration was inhibited immediately by stretch of a jaw opening muscle.

In Fig. 2 the background discharge of 22 spikes/sec. was activated to 44 spikes/sec. by depressing the jaw. This accelerated discharge was completely inhibited by stretch of the ipsilateral digastric muscle, and this inhibitory effect immediately disappeared after release of the digastric (normally jaw depression induces the stretched condition of the jaw closing muscles).

Fig. 3 shows similar responses from the trigeminal motor nucleus, but in
Afferent impulses from jaw muscles

Fig. 2. Discharges of the right trigeminal motor nucleus induced by depressing the jaw are inhibited by stretch of the right digastric muscle.

Fig. 3. Discharges of the right trigeminal motor nucleus induced by stretching the right temporal muscle are inhibited by stretch of the right digastric muscle.

In this case the 40 spikes/sec. of background unit discharge was accelerated to 44 spikes/sec. by stretching the ipsilateral temporal muscle with a load of 100 g.
and the accelerated 44 spikes/sec. discharge was inhibited to 32 spikes/sec. by means of stretching the ipsilateral digastric muscle with the same load. After removing the load from the digastric, the discharge immediately recovered to 44 spikes/sec., and it returned to the initial frequency of 40 spikes/sec. by release of the load on the temporal muscle.

As shown in Fig. 4 a similar reciprocal inhibitory effect was observed between the contralateral antagonistic muscles. That is, unit discharge (14 spikes/sec.) from the trigeminal motor nucleus elicited by stretching the left masseter with a 200 g load was completely inhibited by stretch of the right digastric muscle with the same load, but it recovered again immediately after taking off the load of right digastric muscle.

However, such reciprocal inhibitory interactions between the afferent impulses from jaw opening and closing muscles were not seen in the mesencephalic trigeminal nucleus. As shown in Fig. 5, the background electrical activity of 10 spikes/sec. from the above described point in the mesencephalic trigeminal nucleus was activated to 20 spikes/sec. by depressing the jaw, but no inhibitory effect on these discharges was induced by additional stretch of the digastric muscle, although other small units came into action. Following the release of the stretch of the digastric muscle, these additional small unit discharges disappeared but the former large unit discharge continued. This remaining activity returned to near the initial frequency by releasing the jaw.

2. Stretching the symmetrical muscles; In order to analyze the central interactions of the afferent impulses from the same muscles in both sides in the brain-stem, the paired symmetrical muscles were stretched successively. Unit discharges of 7 spikes/sec. from a point in the trigeminal motor nucleus which were elicited by stretching the left digastric muscle (loading 100 g) were completely inhibited by stretch of the digastric of the other side. After removing the load on the latter muscle, this inhibition was released and discharge returned to initial frequency (Fig. 6).

A similar relation was also observed between both of the jaw closing muscles on each side as shown in Fig. 7. That is, the 10 spikes/sec. unit discharge at
FIG. 5. Discharges of the right mesencephalic trigeminal nucleus induced by depressing the jaw are accelerated by stretch of the right digastric muscle.

FIG. 6. Discharges of the left trigeminal motor nucleus induced by stretching the left digastric muscle are inhibited by stretch of the right digastric muscle during the interval indicated.
the motor nucleus of the fifth nerve induced by stretching the right masseter (load 200 g), was completely inhibited by stretch of the contralateral masseter (load 200 g). These inhibitory interactions between the paired symmetrical muscles were not observed in the mesencephalic nucleus. As shown in Fig. 8, the spontaneous discharges of 9 spikes/sec. at the mesencephalic nucleus were accelerated to 18 spikes/sec. by stretching the left digastric muscle, but this acceleration was not affected at all by either stretch or relaxation of the contralateral digastric muscle.

3. Records with microelectrode; Figs. 9 and 10 show the electrical activity of the trigeminal motor nucleus and mesencephalic trigeminal nucleus recorded with a glass microelectrode (1 μ at the tip). These recordings were of extracellular single unit spike potentials of 500 to 900 μV, spike duration 2-3 msec. In Fig. 9 the frequency of the spontaneous discharge approximately doubled on stretching the masseter with a load of 10 g.
Fig. 9. Records from the trigeminal motor nucleus with glass micro-electrode (1 μ at the tip).
A: Background activity (40 spikes/sec.)
B: During stretch of the ipsilateral masseter (80 spikes/sec.)

Fig. 10. Records from the mesencephalic trigeminal nucleus with glass microelectrode.
A: Background activity (no spike).
B: During stretch of the masseter (18 spikes/sec.)
FIG. 10 shows a record from the mesencephalic trigeminal nucleus which has no firing in the resting state, but the 18 spikes/sec. discharge followed the stretch of the masseter with a 10 g load.

DISCUSSION

LIDDELL and SHERRINGTON demonstrated that increase of tonus of the quadriceps by stretching this muscle was completely inhibited by stretching the biceps-semitendinosus. They attributed this phenomenon to the inhibitory effect of afferent impulses from the latter muscle on the activity of the motoneurones innervating the former muscle.

Similar phenomena have been reported in muscles of the forelimb (DENNY-BROWN and LIDDELL, MILLER) and in eye muscles (SHERRINGTON). However, this phenomenon has not yet been studied in jaw muscles, nor have the precise interrelationships among afferent impulses in the motor nucleus been determined.

The present results show that unit activity of the trigeminal motor nucleus was accelerated by stretching the jaw muscle and that this acceleration was inhibited by stretch of the antagonistic or paired symmetrical jaw muscle, while no such an inhibitory effect was observed in the mesencephalic nucleus. From these results, it is postulated that afferent impulses from a particular jaw muscle activate particular trigeminal motoneurones which innervate that muscle, but that afferent impulses from the antagonistic or symmetrical muscle inhibits the activity of these motoneurones as has been shown for limb muscles. However, these trigeminal motoneuron interactions were not observed in the mesencephalic trigeminal nucleus.

COOMBS, ECCLES and FATT reported that spike potentials of biceps-semitendinosus motoneurones, evoked by antidromic stimulation of the biceps-semitendinosus motor nerve, were depressed by the group Ia volley of quadriceps nerves. The inhibitory effects demonstrated in the present experiments were also presumably mediated by this type of afferent fiber from the muscle spindles of the stretched muscle. All of the firing sources of unit discharges of the trigeminal motor nucleus have not been elucidated, however, it is speculated that Ia afferent impulses from the jaw muscle play an important part in this mechanism.

SUMMARY

The interrelationships in the brain-stem among afferent impulses from antagonistic and symmetrical jaw muscles were studied by means of the microelectrode.

1. An acceleration of electrical activity of the trigeminal motor nucleus induced by stretching a jaw muscle was reciprocally inhibited by stretch of the antagonistic or symmetrical muscle.
2. These reciprocal inhibitory responses were not observed in the mesencephalic trigeminal nucleus.

REFERENCES


